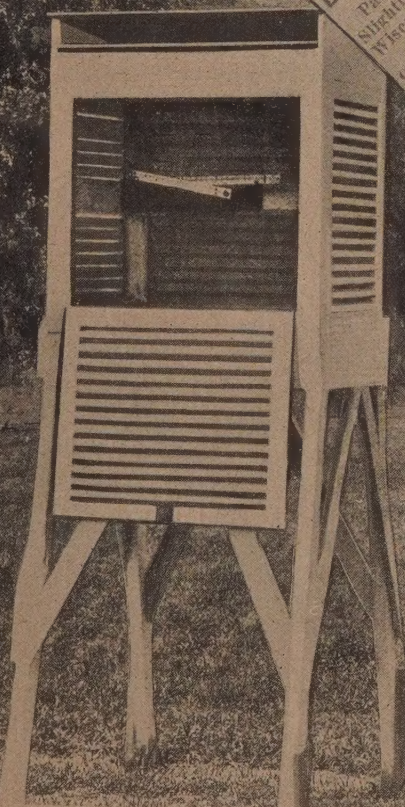


Making Weather to Order for the study of Grain Diseases



WEATHER

Partly cloudy tonight and slightly cooler in extreme eastern Wisconsin tonight.

Report U. S. Weather Bureau

City	Temperature	Precipitation	Wind	Cloudiness
Madison	43	0.0	10	7
Milwaukee	43	0.0	10	7
Chicago	43	0.0	10	7
Green Bay	43	0.0	10	7
Wausau	43	0.0	10	7
Duluth	43	0.0	10	7
St. Paul	43	0.0	10	7
La Crosse	43	0.0	10	7
Minneapolis	43	0.0	10	7
Dubuque	43	0.0	10	7

MADISON WEATHER

Time	Temp.	Humid.	Wind	Cloudiness
Yesterday	43	73	10	7
Today	43	73	10	7
Tomorrow	43	73	10	7
Next day	43	73	10	7
Next week	43	73	10	7
Next month	43	73	10	7
Next year	43	73	10	7

UNITED STATES WEATHER BUREAU EQUIPMENT

AGRICULTURAL EXPERIMENT STATION, THE UNIVERSITY
OF WISCONSIN, MADISON, COOPERATING WITH THE
OFFICE OF CEREAL INVESTIGATIONS, BUREAU OF PLANT
INDUSTRY, UNITED STATES DEPARTMENT OF AGRICULTURE

DIGEST

Weather and seasonal conditions greatly affect crop culture and distribution, especially as these influence plant growth, disease development, and final yield. Page 4

Increased yields and better quality can be obtained only by an intensive study of each crop in relation to its environment, which consists of climate, soil, and disease producing organisms. Page 4

Crop improvement can be placed on a scientific basis if the agronomist, the horticulturist, the plant breeder, the plant pathologist, and the plant chemist cooperating study the plant growth processes under controlled environmental conditions. Page 5

The successful farmer of today has become a practical student of weather and crops. Page 5

Weather is "made-to-order" in the Wisconsin greenhouses for the study of crops and their diseases. The experiment station staff—agronomists, plant breeders, plant pathologists, plant physiologists, and plant chemists—working together is studying the growth and behavior of crop plants under controlled weather conditions. The product of this cooperative work under controlled environment is given in terms of changed crop practices, modified methods of disease control, and new high yielding, disease resistant strains of the principal farm crops which are capable of producing good yields under unfavorable weather. Page 8

"Made-to-order" weather makes it possible to select vigorous resistant seed from these plants in the shortest possible time. This is true first, because the plants are studied in detail under favorable and unfavorable weather and in the presence of disease producing germs, in order to select the best individuals for breeding new strains; and second, because it is possible to secure under controlled weather conditions more worthwhile results in one year than would be possible in a number of years production under uncontrolled field conditions. Page 11

The controlled weather equipment has been modified and used in many commercial enterprises such as large chicken hatcheries, creamery and cheese storage rooms, vegetable forcing greenhouses, and factory processing rooms. Page 11

Making Weather to Order for the Study of Grain Diseases

JAMES G. DICKSON

WEATHER INFLUENCES the distribution, development, and severity of plant diseases. Therefore, it is directly concerned with the practical problems of disease control.¹

The grower has long felt that weather is largely responsible for the rusts, mildew, and scab which reduce the yields and lower the quality of his wheat, oats, rye, and barley. Certainly the parasite (the germ) must be present to initiate the trouble, but the subsequent ravages of the disease are largely determined by the environmental conditions, largely weather, under which crop and parasite are growing.

For example, the fungus causing stem rust is in the grain fields of Wisconsin every year. Stem rust, however, does not greatly damage the grain crops of Wisconsin except in seasons when the weather is moist and warm during the heading and filling stage.

Or again, the wheat scab fungus is present on decaying wheat straw and corn stalks in practically all Wisconsin grain fields; and yet only occasionally does wheat scab ravage the wheat, rye, and barley fields as in 1919 and again in 1924, causing losses which run into millions of dollars. It is time, therefore, that grower and scientist alike were devoting more time and study to the influence of weather, or more broadly, environment upon the growth and yield of the crops, the dissemination of disease germs, the development, and finally, the control of plant diseases.

Each Crop and Disease Responds Differently

The difficulties in controlling weather for crop study are immediately evident to grower and scientist alike. First, no two crops require the same weather conditions for their best development and highest yield; and second, each crop, from the time of seed germination to ripening of grain, requires a different environment, during its progressive stages of growth, to remain vigorous, disease-free, and high yielding. This is even more difficult when disease is considered in the relationship. The parasite, a minute plant growing on or in the host plant, has even a lesser range of adaption to its environment than the grain crop. Or in other words, the wide extremes in climate

¹This bulletin is based upon investigations conducted cooperatively by the Wisconsin Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture. For a more detailed statement see Jour. Agr. Res. 23: 837-870, 1923, Influence of Soil Temperature and Moisture on the Development of Seedling Blight of Wheat and Corn Caused by *Gibberella Saubinetii*, by James G. Dickson.

to which the cultivated crops are subjected, affect differently the various crops and the development of their diseases.

The differences in response of the tobacco and cabbage crops to weather illustrate these difficulties more clearly. The summer of 1915 in southern Wisconsin was very cool and moist, but, that of the next year, 1916, was exceedingly hot and dry. The tobacco crop in the old, "tobacco sick" soils of southern Wisconsin was practically a failure in the cool summer of 1915 as a result of the ravages of the disease known as root rot, whereas in these same fields in the hot summer of 1916 a good crop developed. In contrast, under these same conditions, the cabbage crop in the old "cabbage sick" soils of southeastern Wisconsin was good in the cool summer of 1915 and, due to the ravages of cabbage yellows, practically a complete loss in the hot summer of 1916. Each of these losses was due to a definite disease caused by a specific parasite abundant in the soils of these old fields, but in each case, the development of serious disease was dependent upon suitable weather conditions, regardless of the abundance of the parasite. Thus, in most instances, not only the distribution of the disease, but its prevalence and severity are dependent upon weather, or in general the conditions under which the plant must grow.

Crop Culture Controlled by Weather and Seasonal Conditions

Even more fundamental and basic than disease distribution is the fact that crop culture and variety distribution are largely controlled by weather and seasonal variations. While the average cultivated crop has a wide range of adaption, its profitable production in competition with other crops and the same crop from other regions depends largely upon weather, soil type, soil fertility, and other conditions. The successful farmer, therefore, has become a practical student of weather and crops. He has gained his knowledge largely through observation and experience. He sows wheat and oats early in a cool, moist soil, first because his forebearers had sown it thus and succeeded, and secondly, because he has found by observation and experience that thriftier plants, yielding more bushels per acre, resulted from earlier seeding. His information is general, his practice more or less absolute.

Further advances in increasing yields and quality of crops must be largely by means of a more intensive study of each specific crop in relation to its environment. It is possible to secure pedigree strains of better quality and greater yield (1) by taking advantage of the variations within the varieties of the crop in order to select strains of more vigor, resistance, and range of adaption, and (2) by studying, in detail, the growth of these plants under different weather conditions, in order to give the crop every possible advantage of environment. It is largely by these methods that production costs can be lowered and the quality of farm crops improved.

The burden of the responsibility for this detailed study rests with the experiment station, where the agronomist, plant breeder, pathologist, and others must work, co-operatively, upon the problem. The crops must be studied singly, under varied growing conditions, to determine the combination best suited for growth and yields and the range over which profitable production may be expected. This problem, in its fundamental form, is a study of the influence of fertility, moisture, temperature, light, etc., upon (1) the cycle of seasonal changes of parasites causing the principal diseases of the crop, and upon (2) the complex interrelationship between host and parasite in disease development. Or, in relation to disease development and disease control, it consists in a study of the numerous conditions which, acting together, constitute the environment and their influence upon nutrition, growth and production of the crop plant upon which the disease is developing, on the one hand, and upon the germ, or parasite, producing the disease on the other. With such a study as a foundation it is possible to select vigorous, disease resistant, high yielding strains of the various crops, to modify seed treatments or spraying practices to control disease, and to adjust cultural practices to suit the individual crop in question.

The following experiments pertaining to the chief cereal crops of Wisconsin especially corn, wheat, and oats, and their relations to weather are simply examples of one group of the problems upon which co-operative study has been undertaken. Similar investigations are in progress with the garden crops, especially cabbages and onions, and the apple and cherry in the fruit crops.

Two Methods Used

The experiments with weather and disease development were conducted in the field and in the greenhouse. By making a succession of field plantings, it is possible to get variations in soil temperature, soil moisture, and light conditions. The seasonal fluctuations of any season are great enough to secure high or low soil temperatures, high or low soil moistures (See Figs. 1 and 2) and cloudy or clear weather of sufficient duration for seedling experiments during March, April, May, or early June, by simply watching the moisture and temperature records and the weather bureau reports and predictions. All of the experimental work started in the field is repeated and checked under controlled temperature, moisture, and light conditions in the greenhouses where the various weather conditions can be produced and modified at will. Thus, by checking the field experiments with controlled constant weather conditions, it is possible to study, both separately and combined, the influence of the various factors of the environment.

Seasonal Weather Varies

Continuous field, soil, and air temperatures have been taken during the growing period, at Madison and at Racine. The recording ther-

mometers, or thermographs, have been placed in the experimental field to record the air temperature six to eight inches above the soil and the soil temperature two to four inches below the surface. In addition, regular mercury thermometers and maximum and minimum thermometers were used to check the recording instruments.

The soil moisture in the first six inches of soil was also determined at Madison. Samples were taken at regular intervals three times each week and daily after each rainy period or other unusual condition causing rapid changes in soil moisture.

These records have been obtained during the growing season since 1915. Such records supplemented by the records of air temperature, relative humidity, sunshine, wind behavior, etc. available from the local weather bureau office, have made it possible to study both sea-

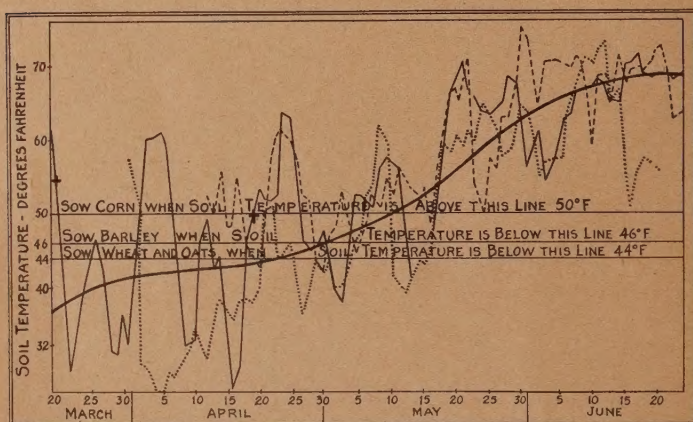


FIG. 1.—SOW CROPS ACCORDING TO THE WEATHER AND TAKE ADVANCE OF SEASONAL FLUCTUATIONS

The light lines show the mean soil temperature for each of three years. The heavy line shows the average mean soil temperature computed from these. The heavy line indicates that a cold soil may be expected during March and early April, the general time to seed wheat and oats; a cool soil the latter half of April, the regular period to seed barley; and a rapidly warming soil during late April and May the general season to plant corn. The light lines show wide fluctuations in soil temperature from week to week during late March, April, and May. By watching the weather, it may be possible to make sowings of wheat and oats very early. For example on March 18, 1921 (the place marked on the figure), the soil so warmed up and dried out that all the spring wheat could be sown before the temperature went down to freezing on March 28. This early sown wheat out-yielded all the subsequent wheat seeded because of the warm spring (See page 28 for details). And again, that same year by watching the weather, and weather records, it was possible to plant corn on clean, clover land prepared the previous year on April 19 and 20, (the place marked with a † on the figure). Fire-dried, disease-free seed was planted on clover land during this ten days of warm weather. The corn was well out of danger of seedling blight and rots before the short cold spell of May 1 which delayed regular corn planting nearly two weeks. The result was a high yield of well matured corn. (See page 18 for details of corn and weather).

sonal and daily weather conditions in relation to plant growth and to disease development.

The records have shown wide seasonal variations as well as periodic and daily variations of large latitude. (See Figs. 1, 2, and 3.) For example; the season of 1915 was very cold and moist in contrast to an extremely hot and dry season of 1916. Or again, the 1920, 1921, and 1925 soil temperatures, although varying widely from week to

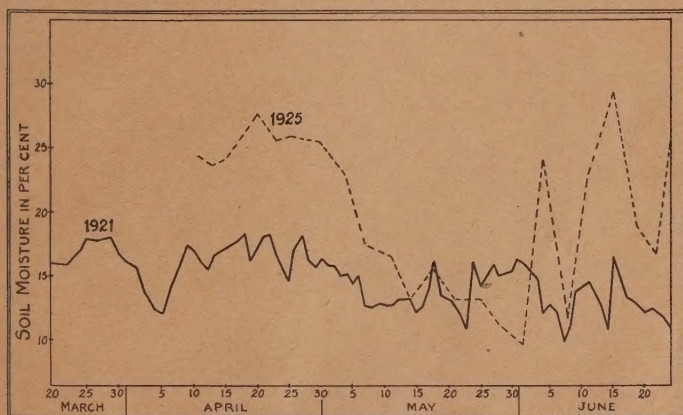


FIG. 2.—SOW CROPS IN A MOIST OR DRY SOIL DEPENDING UPON THEIR REQUIREMENTS

Field soil moisture varies widely from season to season. Note the contrast between the soil moisture for 1921 and 1925. In 1921, the soil moisture fluctuates from week to week but was fairly uniform at an average moist condition all spring. In contrast, in 1925, the early spring period was very dry, followed by an extremely wet soil in April, and returning to about normal in May. Most small grains were sown in 1925 before the wet April weather and germinated in the dry soils; as a result, oat smut was abundant this season. Oats sown April 15 to 20, just before the wet weather, were free from smut as soil moisture influences oat smut development (See page 14.) Or again, barley seeded April 9, which germinated in a wet soil, was badly damaged by stripe whereas that sown in early May, in a dry soil, was free from stripe (See page 35).

week, were very similar especially through the growing seasons. (See Fig. 1.) Likewise, soil moisture varies from season to season as well as periodically. (See Fig. 2.) These seasons of 1921 and 1925, relatively similar in regard to soil temperature and yet so widely different in regard to soil moisture, serve to illustrate the wide local variation in weather, from season to season and from week to week, within any one season.

It is this wide fluctuation in weather which makes it so difficult to study temperature, moisture, etc. in detail in relation to the other factors of environment. And yet it is this fluctuation in weather which makes it possible to plant crops under conditions favorable for their best development. In other words, the successful farmer plants by the weather and not by the calendar.

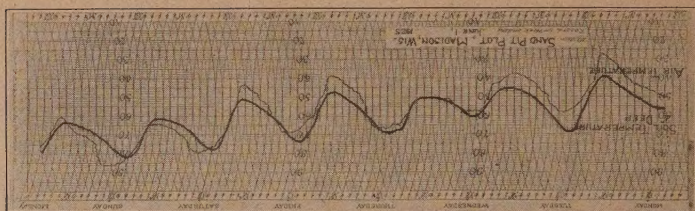


FIG. 3.—SURFACE SOIL TEMPERATURES FLUCTUATE WITH AIR TEMPERATURES

Both show the greatest daily range in the spring and early summer when most seeds are germinating; this range often extends from the freezing point in the night to summer heat at midday.

In the greenhouse experimental work such fluctuations can be "made-to-order" to study their effect on seedlings (Figs. 5 and 6).

Weather Made to Order in the Greenhouse

The detailed experiments on the influence of soil temperature, soil moisture, air moisture, etc. upon the development of the plants, the

Some Planting Time Suggestions

Sow oats in a cold, wet soil at the earliest possible date in the spring to control oat smut and seedling blight, and obtain high yields.

Sow flax the earliest possible date in the spring to prevent flax wilt. Wilt resistant, high yielding strains of flax are available to further insure a profitable crop.

Plant field selected, well cured corn, in a warm soil on clover or alfalfa land to prevent seedling blight and insure good stand. Cold resistant, disease resistant, high yielding new strains of corn are being produced to increase yield and lower production costs.

Sow wheat in a cold soil, at the earliest possible date in the spring and latest safe date in the fall, to prevent seedling blight and insure high yields.

Sow pedigree, disease-free barley after the danger of cold wet soils has passed to prevent barley stripe.

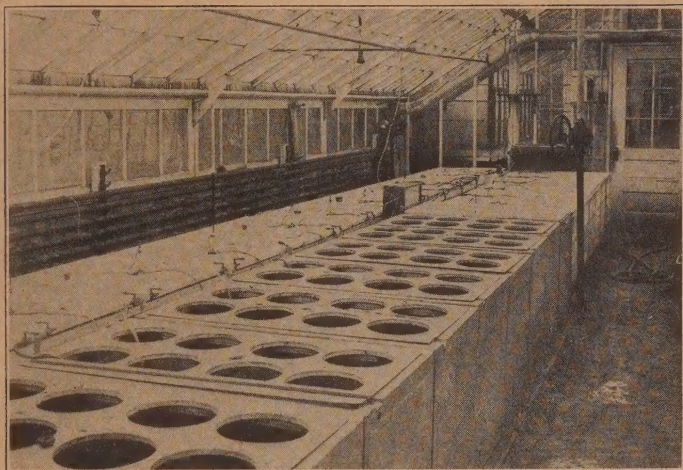


FIG. 4.—WHERE SOIL TEMPERATURES ARE “MADE-TO-ORDER”

The Wisconsin soil temperature tanks, as shown ready for use in this greenhouse, consist of a watertight box with a cover in which the cans of soil are suspended. The tanks are filled with water which is heated to the temperature desired by electric heaters. The heater is controlled by a thermostat which regulates the temperature. The cans of soil suspended in the water are thus cold or warm depending upon the water temperature maintained.

parasites, and the diseases, are conducted in the greenhouse under controlled conditions. The soil temperature experiments are conducted largely in the Wisconsin soil temperature tanks, large, insulated, wooden boxes with a water-tight, galvanized iron lining. These tanks are filled with water, and the soil containers which are water-tight, are suspended in these water baths. The temperature of the water is maintained by running in cold water to lower the temperature slightly below that

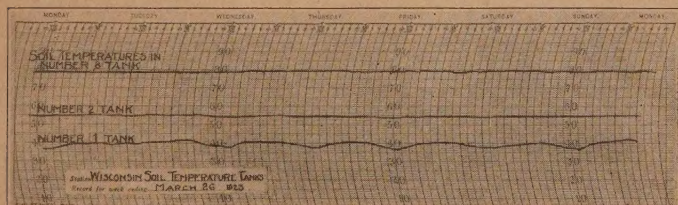


FIG. 5.—SOIL TEMPERATURES ARE CONTROLLED IN THE WISCONSIN SOIL TEMPERATURE TANK

The tanks are arranged in series of six to eight, operating over a range of about 40°F. at intervals of 30 to 40. Note the soil temperatures maintained for an interval of one week in tank No. 1 operating at 40°F., a good temperature for germinating wheat, tank No. 2, operating at 55°F., and tank No. 8, operating at about 80°F.

desired and then heating to the temperature desired with a thermostated electric heater. (See Fig. 4.) These unit tanks are arranged in series of six or more and operate at temperatures ranging from cold (50°F.) to hot (104°F.) (See Fig. 5.)

In addition to these constant temperatures, equipment is available for alternating high soil temperatures during the day and low soil temperatures at night. (See Fig. 6.) With such equipment, the constant soil temperatures can be compared with the alternating temperatures such as occur under field conditions.

In addition to the temperature tank series, large glass chambers have been constructed in which air temperature and air moisture are controlled. These chambers consist of a glass cage, 5 feet in dimension

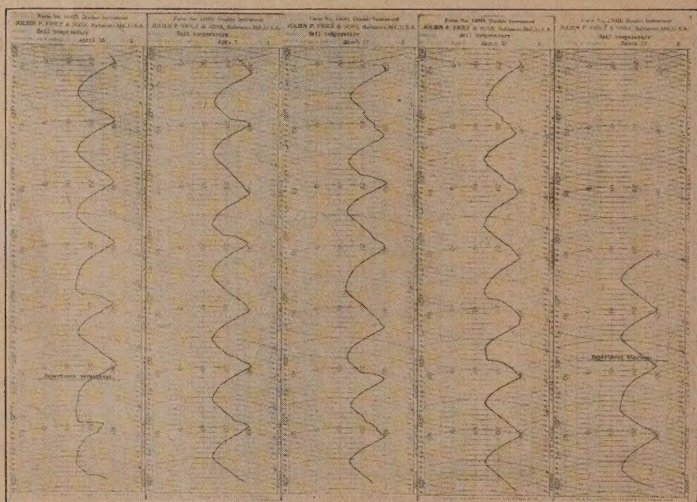


FIG. 6.—SOIL TEMPERATURES ARE “MADE-TO-ORDER” IN THE WISCONSIN SOIL TEMPERATURE TANKS

Record sheet showing alternating high and low soil temperatures over about the same range as occurs under field conditions during late spring. These soil temperatures are obtained by having cold water turned into the tank in the afternoon through an automatic valve operated from a clock mechanism. The cold water is shut off during the early morning hours and the electric heater turned on. It is possible to produce controlled soil temperatures having a range comparable to field conditions. For details of this equipment see Jour. Agr. Res. 26; 205-209, 1923. Influence of soil temperature and moisture in infection of wheat seedlings by *Helminthosporium sativum* by H. H. McKinney.

on all sides, mounted on a base which contains the heating and cooling equipment. The air is circulated, gently, over the heating or cooling coils depending upon the temperature desired. It is then passed through a tempered water spray to add the proper amount of moisture, and slowly circulated through the chamber and out again to be tempered and

returned, or discharged as the experiment demands. (See Fig. 7.) It is possible to grow quantities of plants under constant conditions of moisture and temperature (Fig. 8) by keeping them in the same chambers or under alternating conditions by shifting them from the high to the low temperature or moisture in the respective chambers.

In addition to these chambers, four greenhouse units, each 20 feet square, have been equipped with temperature and moisture control apparatus so that the entire house is under adequate control. This equipment makes available for plant growth studies "made-to-order" climates comparable to northern Wisconsin, southern Wisconsin, southern Illinois, and the extreme southern United States all, side by side, and operating constantly. Corn, wheat, peas, beans, apples, and pears may be grown, simultaneously, in these different artificial climates. Crop development in its various stages, disease development, disease control such as seed treatment or spraying, and testing and selecting disease resistant varieties and strains may be carried on and studied in detail in this equipment.

Experiments in this "made-to-order" weather equipment, when checked with field plantings made at different dates, in different locations, and under different weather conditions, enable the scientist to study the crops in all their various stages of development. By means of this study, he is able to select high yielding, resistant strains or to adjust the existing practices to those best suited for the highest yield from that particular crop. In addition, it is possible to secure, under controlled weather conditions, more worthwhile results in seed production of special strains than would be possible in a number of years of observation and selection under field conditions.

The following examples give briefly some of the results obtained in studying certain of the cereal crops under these various weather conditions. The results, while incomplete, illustrate the progress in crop improvement possible with this method of study. Similar studies are in progress with other field crops, notably tobacco and potato, the garden crops, especially in connection with cabbage and onion diseases, and the fruit crops, particularly in relation to the disease development and spraying programs for apple scab and cherry leaf spot. The details of these results appearing in other bulletins and scientific papers illustrate even a wider range of application of these methods in crop development than reported in connection with the cereal crops.

Weather Influences Smut Development

The grain smuts, like the rusts, were among the first diseases to be observed by the growers and to be studied by the earlier scientists. The development of the smuts, while not so directly influenced by weather as the rusts, is nevertheless closely associated with weather conditions both in regional distribution and seasonal development. The earliest pathologists and agronomists noted, through observation, the relative absence of the oat smuts in the New England states and northern Mississippi Valley regions in contrast with usually heavy losses in Iowa, Kansas, and the southern Great Plains region.

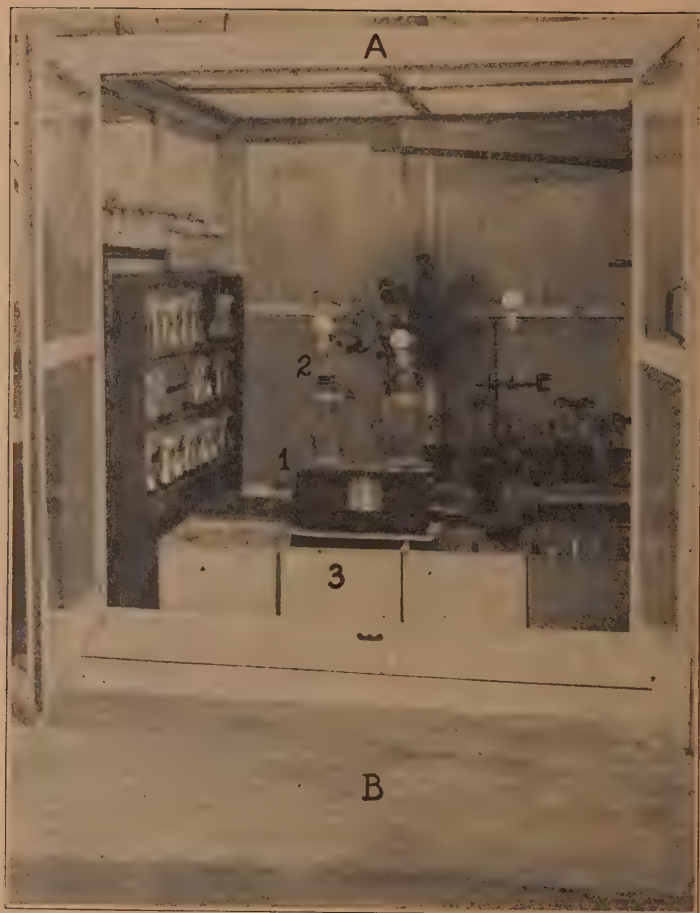


FIG. 7.—WEATHER IS “MADE-TO-ORDER” IN THIS CHAMBER USED FOR THE STUDY OF PLANT DISEASES AND THEIR CONTROL

Each chamber consists of a large glass compartment (A) in which the plants are grown, placed upon a concrete base (B). The refrigeration coils, for cooling and drying the air, and the heating coils for heating the air, are placed in well insulated compartments within the concrete base (B). The air is passed through the heating or cooling coils depending upon the position of the two-way damper in the air outlet from the base. The position of the damper is controlled by the thermostat placed within the chamber and operating by means of compressed air acting upon a diaphragm valve. The tempered air is then passed through the humidifying chamber or directly into the glass chamber depending again upon the position of the two-way damper operated by a humidostat. The tempered and moistened air then enters the glass chamber at the top, passes slowly around the plants growing within and is discharged at the bottom, or recirculated through the base again as the experiment demands. The instruments used for recording temperature, relative humidity (1), and measuring evaporation rate (2) are shown within the chamber. The metal boxes in which the plants are grown (3) are placed on the floor of the glass compartment.

Experiments conducted under controlled soil conditions have shown that soil temperature and moisture greatly influence the smut infection during the early seedling stage. The oat smut spore germinates in the soil forming many minute secondary spores which germinate and penetrate the young oat seedling before the sprout is one-half inch long. Unless the smut germ enters the oat sprout before it reaches one-quarter to one-half inch in length the outer coverings of the sprout become too tough to permit penetration by the smut germ and the oat plant is safe in so far as smut is concerned.

The experiments conducted under controlled weather conditions

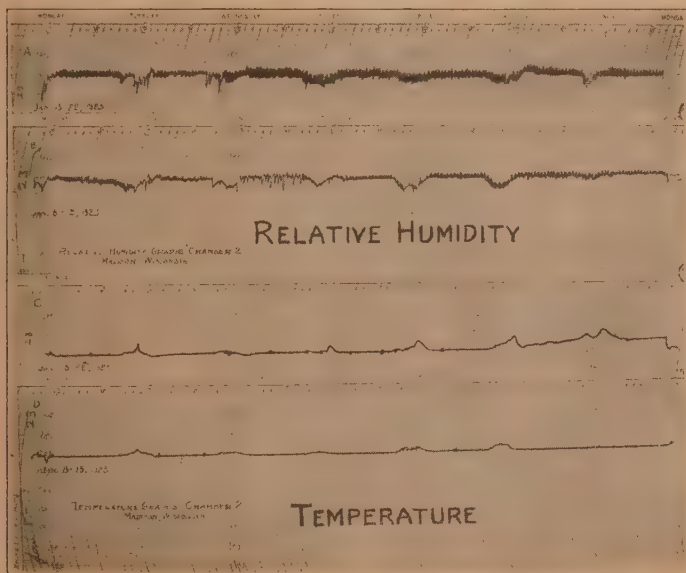


FIG. 8.—WEATHER “MADE-TO-ORDER” IN THE CHAMBERS

Showing two weekly records each, of relative humidity and temperature control, of the air in chamber No. 2 operating at about 20°C . (70°F .) and a relative humidity of 80 per cent. Temperature and moisture are changed in the chambers to meet the demands of particular experiments as explained under Fig. 7.

showed that high soil temperature reduced the amount of oat smut development as did also very low soil temperatures. The temperatures during the ordinary period of sowing oats in the spring were very favorable for smut infection and development. Wet soils, especially when the temperatures were high, reduced the oat smut infection entirely whereas a relatively dry, moderately cool soil furnished ideal conditions for germination of the oat smut spore and infection of the oat plant. Under these latter conditions all of the plants were smutted.

These experiments under the controlled conditions, therefore, help explain the differences in the amount of smut developing in Vermont and Kansas fields. In the former case, the cool, well tilled, usually moist soils of the smaller fields of Vermont with frequent spring rains tend to prevent oat smut development. While, in the latter case, the Kansas soils, warmer and usually fairly moist during the spring with less rainfall during the seeding period, offer favorable environmental conditions for oat smut development.

It is interesting to check these results under controlled weather conditions with the results obtained in field experiments at Madison. Heavily smutted oats were sown in well prepared soil three consecutive springs, 1922 to 1924, all of which were widely different in weather conditions during the period the oats were germinating. In 1922, the seed was sown May 3 in a moist, moderately warm soil (66°F.). A rainfall of .28 inches fell in the four days following sowing, after which the soil remained wet during the germination period. Under these conditions less than one plant per rod row was smutted, or less than .3 per cent.

On May, 25, 1923, the same variety of oats equally heavily smutted was sown in a moist soil during a moderately warm period (60°F.). The soil moisture decreased gradually during the germination period for there was no rainfall until after the seedlings had emerged. Under these weather conditions an average of 113 plants per rod row were smutted or about 56 per cent. In 1924, the oats were smutted and sown May 22 in a moist cold soil (52°F.). Rain fell the morning following seeding and continued four days with a total precepction of .2 inches;

TABLE 1.—WEATHER CONDITIONS INFLUENCE OAT SMUT DEVELOPMENT

Date of seeding	Weather conditions during germination			Average smutted plants per rod row
	Temp. °F.	Soil moisture during germination	Rainfall during germination	
1922, May 3.....	66	Very moist	.28 in first 4 days after seeding	.3
1923, May 25.....	68	Moist	.0 during germination	56.0
1924, May 22.....	52	Very moist	.4 first 4 days after seeding	1.5

the soil was wet throughout the germination period. Under these conditions of a wet cold soil three plants per rod row developed smut at heading, or about 1 per cent (See Table 1.) Quite obviously the difference in soil moisture content during the period of germination and smut infection played an important role in determining the smut development in these experiments.

There were greater losses from oat smut in 1923 than in any previous year over which observations were recorded, whereas in 1924, there was relatively little or no loss even after sowing the heavily

smutted oats grown the previous year. Thus, spring weather conditions largely control the development of oat smut and determine not only the regions in which oats are generally smutted but the amount of smut developing from year to year within these regions.

Fortunately this disease is easily controlled by treatment with formaldehyde or copper carbonate and, therefore, the grower who systematically treats his oat seed takes no chance with the weather and smut development. The grower who treats the oats by soaking the seed 15 minutes in a solution of 1 part commercial formalin to 320 parts water, or dusting thoroughly with copper carbonate if the seed is of unknown origin or known to have smut spores on it, and then sows at the earliest possible date in the spring in a cool, wet soil has doubly insured his crop against smut and against the seedling blight disease which does not develop in a cool moist soil. This type of farmer is sure of a high yield of good quality oats which will mature before the rusts have opportunity to develop as a further enemy to the crop during the hot, moist July days. The successful farmer plans his work to take advantage of weather conditions in growing not only his oat crop but all of the crops he produces in his diversified farming.

Weather conditions also influence the development of the other cereal smuts. Unfavorable weather conditions for the development of bunt or stinking smut of wheat and the loose smut of wheat are largely responsible for the absence of these two serious wheat diseases in Wisconsin. Cool spring weather which prevents germination of the corn smut spores, together with the cutting of the corn for ensilage, help to control the heavy spread of corn smut in the state and limit it to a late spread of the smut on the tassel and ear after the soil has warmed up sufficiently for germination of the smut spores.

Warm Weather Favors Flax Wilt

Flax wilt develops in a warm soil. The disease is caused by a parasitic fungus which develops in the vascular system, or interior of the stem, of the flax plant causing a yellowing, wilting, and finally the death of the plant. When once introduced into the soil it persists indefinitely and, in regions where flax is grown intensively, soon becomes prevalent enough to reduce greatly grain flax yields. Such soils have been termed "flax sick" by the grower and abandoned for flax culture. Largely, as a result, the flax industry has gradually pushed westward with the opening of new soils.

Early experiments in the greenhouse showed that soil temperatures influenced the development of wilt. The plants, grown in the cool soil, did not wilt whereas, those grown in the very warm soils wilted and died during the seedling stage. (See Fig. 9.)

The flax plant develops best in a cool soil or below the temperatures where the most wilt develops. The plants grown at 53°F, or below, were stocky, vigorous seedlings free from wilt and made a good subsequent growth.

The geographical distribution of flax wilt and differences in severity

of the disease from year to year, agree with the greenhouse results. The wilt develops when flax is sown in an infested soil late in the season or in a warm season. In cool seasons the fields are relatively free from wilt.

The wilt, as well as flax canker, caused by hot soils, are avoided by planting flax early in the spring when the soil is cool. Thus, flax seedlings, developing in the cool soil, grow past the stage where they are susceptible to wilt and become large enough to shade the ground before the warm weather commences.

Wilt resistant strains of flax have been developed by selecting plants free from wilt under conditions favorable for the production of the disease. In this way new varieties have been made which will withstand

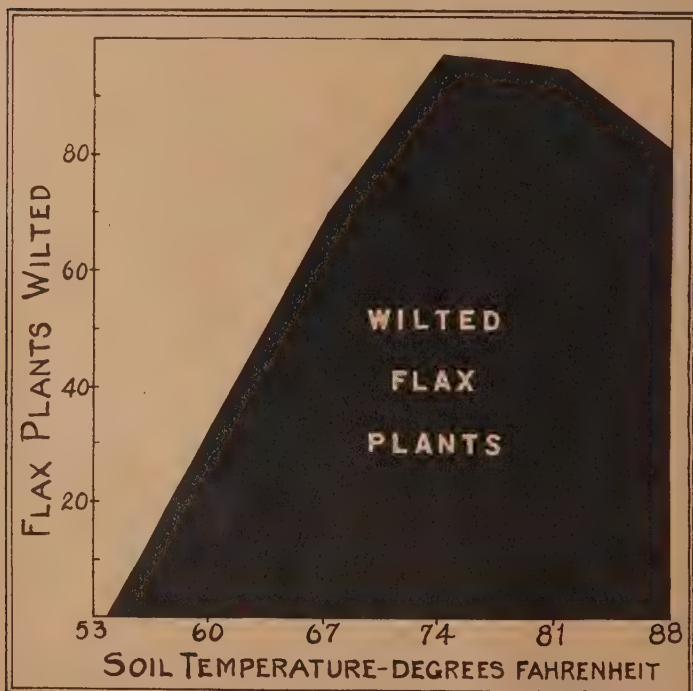


FIG. 9.—SOW FLAX IN A COOL SOIL TO PREVENT FLAX WILT

Note the rapid increase in the percentage of flax plants wilting with the rise of soil temperatures above 54°F. Wilt resistant strains of flax have been developed by selecting plants which resisted wilt even at high soil temperatures and using the seed from these plants to start new lines. Even the wilt resistant flax plants succumb to disease when grown in flax sick soils after the soil temperature is above 60°F. Increase flax yields and avoid disease losses by using resistant seed and by seeding early in a cold soil.



FIG. 10.—PLANT CORN IN A CLEAN, WELL TILLED, MODERATELY WARM SOIL FOR GOOD ROOT DEVELOPMENT, VIGOROUS GROWTH, AND HIGH YIELDS

Contrast the root development of Golden Glow seedlings grown at 54°, 60°, and 75°F. A moderately warm soil, 60-75°F. produces vigorous growth with a large, well developed root system.

the wilt development over a much greater range of unfavorable conditions, including high soil temperatures, and produce a good crop every season. The use of these wilt resistant varieties, combined with good preparation of the soil and early planting, have largely overcome the loss caused by flax wilt.

Cold Weather Increases Corn Seedling Blight

Other examples will serve to illustrate not only how weather influences disease development but also how this knowledge can be utilized in disease control. The studies upon the development of corn seedling blight in relation to weather conditions illustrate how a better understanding of the development of the disease in relation to its environment has helped in the modification of crop practices and selection of blight resistant corn. The experienced grower well knows that cold, wet spring weather causes the corn to rot in the ground but he does not always know just why, nor how to prevent the loss. The study under controlled weather and field conditions has shown some of the causes and their relation to weather and has made possible, thereby, the general control of the rotting.

Corn a Warm Weather Crop

Corn is normally a warm weather crop. Due to the fact that the corn crop is composed of widely different individual plants, which condition has enabled the grower to produce the crop from Canada to the tropics, it requires a relatively warm soil in which to germinate and grow. The corn seedling develops rapidly at high soil temperatures, and in general the higher soil temperatures hasten growth and maturity. The stockiest, strongest seedlings, with the best developed root system, are developed at about 70°F., (late May temperatures) with the strains and varieties adapted to the northern portion of the corn belt. Although certain strains have been selected which will grow well at 53° to 60°F., (late April temperatures) in general the seedlings grown at temperatures below 60°F., (early May temperatures) are soft, watery, and easily succumb to disease. (See Fig. 10.) For example, corn planted at Madison, Wisconsin from April 15 to May 30 at weekly intervals when moisture conditions, are similar gives the best stand of larger plants and the highest yield when planted after May 15 and before May 30. Similar experiments conducted in other states, show that corn sown in a well tilled soil after it has been warmed thoroughly in the spring gives a better stand, higher yields, and matures as early as corn planted earlier, in April or early May, in a cold soil. Corn planted later than the last week in May grows well until the dry hot midsummer weather, which usually occurs at the time this late sown corn is tasselling, or the period when the corn plant requires the largest amounts of water and soil food materials, and as a result these late sowings usually give low yields and later maturity. The period for corn planting in the northern portion of the corn belt, therefore, is short, usually being limited in Wisconsin to the middle part of May.

Cold Resistant Strains Have Been Obtained

As the length of the growing season is one of the most important factors in corn production in this northern region, it is highly important to secure, by selection and breeding, strains (new varieties originating from a single plant) which will grow at lower temperatures in the spring and withstand moderately cold weather during ripening in the fall. Such selections have been obtained in connection with these temperature studies and are being produced for general distribution later. Several strains of high quality Yellow Dent Corn² have been obtained which germinate and develop well at 53°F., and also will continue to grow in the fall after freezing nights occur. They usually remain green two to three weeks after the ordinary varieties and other strains growing alongside have been killed by frost. These strains have also proven very resistant to seedling blight and corn smut. By using

²This work has been conducted cooperatively with J. R. Holbert, Agronomist, Office of Cereal Investigations, Bureau of Plant Industry, Funk Bros. Seed Co., and recently also in cooperation with the Departments of Agronomy and Genetics at the University of Wisconsin.

these strains on well tilled, fertile, disease-free soil it has been possible to lengthen the growing season one to two weeks and thus materially increase the yields.

Seedling Blight Common in Cold Soil

One of the chief factors in reducing the yields of corn throughout this state and the entire corn belt is disease, especially the seedling blights and corn root rots. The parasites causing these diseases, or complex of diseases, live in the soil, on the crop refuse of many of the crop plants but especially the small grains and corn. They continue to develop in the soil indefinitely and, whenever weather conditions occur which weaken the corn plant and enable the organisms to attack the plants, blighting and rotting occur. These similar diseases are more closely associated with weather conditions in their development than even the rusts. For they do not develop even though the parasites be present unless by unfavorable weather the plant is unbalanced in its growth.

Field observations and records have long shown this relationship with weather. Numerous recent experiments, under controlled weather conditions, have given a better understanding of how temperature, moisture, fertility, light, and other factors, all intermingled, influence the development of the corn plant and the diseases and have made possible the selection of disease resistant, cold resistant, high yielding strains of corn with the plant, ear, and kernel types demanded commercially.

Soil temperature and moisture experiments demonstrate that seedling blight develops in a cold soil. Two varieties of Yellow Dent corn, Ninety Day and Golden Glow, were grown in large cans of soil under controlled temperature and moisture conditions. The corn, at the time of planting, was inoculated with the spores of the seedling blight parasite (*Gibberella saubinetii* (Mont.) Sacc.) or the kernels were sown in soil infested with this parasite. The soil was maintained at constant temperatures, ranging from 53° to 83°F., and different moisture contents, ranging from a very dry to a very wet soil.

These experiments show that seedling blight develops in both Ninety Day and Golden Glow corn seedlings at soil temperatures below 74°F. The disease does not occur in serious form, however, except below 60°F. At these low soil temperatures, corresponding to early May field soil temperatures, most of the seedlings were blighted, before or immediately after emerging from the soil under all of the different soil moistures. Above 74°F. less blighting occurs, unless the soil is very dry, and all plants develop practically as well in the disease infested soil as in the disease-free soil. (See Table II and Figs. 11 and 12.)

Field plantings with this same corn, at different dates in disease-free soil and soil infested with the seedling blight organism, show practically the same temperature and moisture relations. The early plantings, made before the soil is warm, blight badly in the infested soil,

whereas the plantings made later, after May 15, are free from disease. (See Table III and Fig. 13.)

These results emphasize the importance of using good seed and soils free from these root rot parasites if corn is to be sown earlier than the middle of May. (See Fig. 14.) Many of the successful corn growers of the state are taking advantage of this fact by sowing disease-free corn which has been fire dried and stored in a warm dry place on well prepared clover, alfalfa, or meadow land. Some of the successful seed growers of the state, by following this practice, are sowing corn the first of May and securing an increased yield of well matured seed.

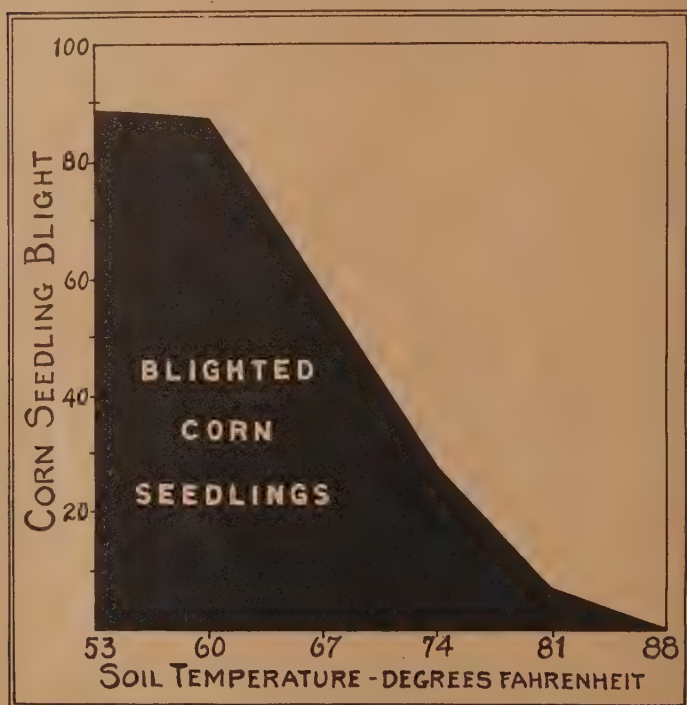


FIG. 11.—PLANT CORN IN A WARM SOIL TO PREVENT SEEDLING BLIGHT

Poorly cured, diseased seed corn or good corn planted in old corn or wheat land will rot when planted in a cold soil. Note that 85 per cent of the corn plants were killed by seedling blight caused by the wheat scab organism at soil temperatures below 60°F. in contrast with less than 10 per cent in a warm soil, above 75°F. Diseased, poorly cured seed should be planted in a warm soil to prevent seedling blight. Corn put on old corn or wheat land should be planted in a warm soil to prevent seedling blight and poor stand.

Plant disease-free, fire-dried pedigree corn on clover or alfalfa land moderately early to prevent seedling blight and secure the highest yield of well matured corn.

The seedling blights and root rots of corn in Wisconsin can be controlled. Selecting seed in the fall from plants that are vigorous and remain green until the ear is ripe and the husks dry, insures against seedling blight the following spring. Ears from weakened plants or stalks that are down, as well as prematurely dead stalks, that is, those with dead leaves and tassel early in the season should not be selected for seed as they are diseased and will give weak, diseased seedlings the following spring. These seed ears should be fire dried immediately at temperatures between 75° and 85°F. until hard and dry or until the moisture is reduced to between 12 and 15 per cent. This seed should then be stored for the winter in a warm dry place to prevent weakening of the germ by unfavorable winter weather. When sown on clean,



FIG. 12.—COLD SOILS, POOR SEED, AND DISEASE INFESTED SOILS PRODUCE SEEDLING BLIGHT AND POOR STAND

Well cured Golden Glow corn was planted in soil in which the seedling blight parasites were abundant. The soil in one lot was kept cool (60°F.) and in the other warm (75°F.). All the plants in the cool soil blighted and rotted before emerging (left). In contrast, all of the plants in the warm soil were healthy. Plant corn so it will germinate in a warm soil as early as possible in the spring.

well prepared clover or alfalfa land such seed can be planted early in May. If sown on old corn or wheat land the planting should be delayed until the soil is warm, usually after the middle of May.

TABLE II.—SOIL TEMPERATURE INFLUENCES THE DEVELOPMENT OF SEEDLING BLIGHT OF CORN

Soil temp. °F.	Germination		Decrease in germination caused by disease	Healthy plants		Decrease in healthy plants caused by disease
	Clean soil	Disease infested soil		Clean soil	Disease infested soil	
Degrees F	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
46	50	0	50			
53	77	20	57	72	11	61
60	96	54	42	92	12	50
68	97	89	8	95	42	53
75	92	100	0	92	73	19
82	100	94	6	100	93	7
89	97	100	0	90	100	0

Disease and Cold Resistant Corn Strains Result from Studies

Disease resistant, vigorous growing strains of corn have been secured which will grow at much lower temperatures than the average for the variety from which the strain was selected. In the earlier weather experiments with corn, both in the greenhouse and in the field, a limited number of seedlings, always occurred which grew at low tem-

TABLE III.—PLANTING CORN TOO EARLY IN THE SPRING ON DISEASE INFESTED SOIL RESULTS IN A POOR STAND

Date of planting	Average percentage stand	
	Disease-free soil	Disease infested soil
April 20	90	20
April 30	91	78
May 21	94	93

peratures even in disease infested soil. A large number of individual plants within the standard varieties studied were self-pollinated and grown the successive seasons in disease infested soils under weather conditions favorable for disease development. The best plants which showed desirable characteristics were again selected and self-pollinated to further purify the strain or eliminate undesirable characters. After continued selfing and selection, strains have been developed which under unfavorable conditions, breed true for their resistance to disease. Two

or more of these desirable strains are then cross-pollinated to produce new high yielding, disease resistant varieties of corn.³

While these new strains are not immune to disease, they are resistant even under unfavorable weather conditions, and have given good stands of healthy plants and high yields of corn when sown in cold soils in the presence of the seedling blight parasite.

The recombination of several of these high yielding, resistant strains has given a synthesized variety (a variety made by putting together several pedigree selfed strains) of good quality and high yielding capacity even under unfavorable growing conditions. The scientific study of the reaction of the crop plant to its environment, consisting of weather, soil fertility, disease, etc., has led to the determination of the range of conditions over which the plant will function normally in its growth and yield of grain or fruit. This is followed by the selection of varieties, or individuals within the variety, which have a greater capacity to withstand unfavorable growing conditions and thus at a minimum increase in cost of production, further insures the yield against weather, disease, and other conditions.

Warm Weather Favors Wheat Scab and Seedling Blight of Wheat

The wheat plant, unlike corn, is a strictly cool weather crop. While it is grown from the central southern states to the extreme northern frontier of farming in Canada, it is grown successfully only where there is a cool season during the seedling and tillering stages of development. Here again, the wheat crop, although much less variable within a variety than corn, has been adapted to widely different climates. As a result, the winter wheats are sown almost universally in the southern and central United States where they develop in the cool fall, winter, and early spring, maturing in advance of the summer heat. And again, the spring wheats alone are sown in the northern United States and Canada where they develop during the long, cool spring and early summer.

The practical wheat grower recognizes fully the importance of a cool soil during the early period of growth of the wheat plant if it is to resist successfully the hot, dry weather of early summer and yield a full crop. He has acquired this general knowledge through years of experience. He does not know, however, the influence of this cool soil upon seedling vigor, resistance to disease, growth of a large root system, production of a large number of tillers, and the processes by which this growth is made.

Wheat Yields Best in Cool Soil

Field and greenhouse experiments, alike, have shown the relation of cool weather, during the growth period of winter and spring wheat, to

³This work has been continued along with the study of the influence of weather on disease development in cooperation with J. R. Holbert of the Office of Cereal Investigations, Bureau of Plant Industry, and recently also in cooperation with the Departments of Agronomy and Genetics of the College of Agriculture, Wisconsin.

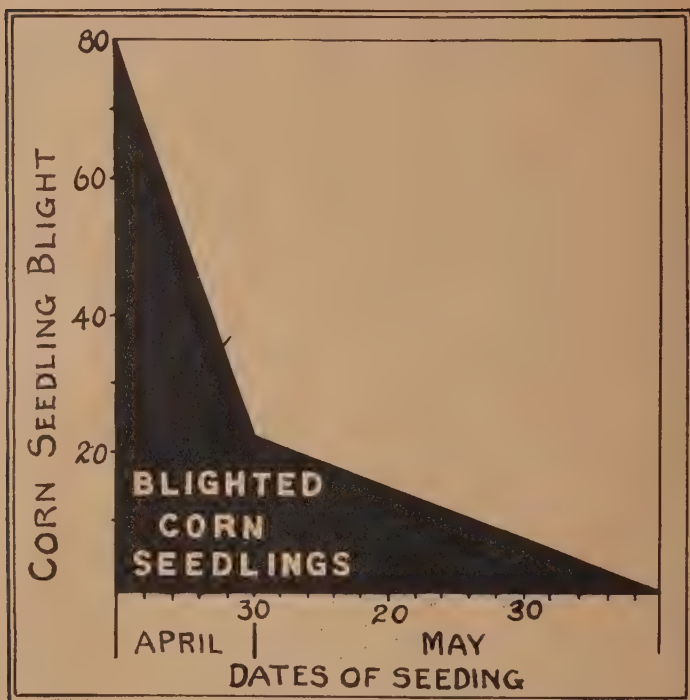


FIG. 13.—PLANT CORN BY THE WEATHER, NOT THE CALENDAR

Cold soils produce seedling blight with poor seed on corn land. The remedy: plant disease-free, fire dried seed on clean land (alfalfa or clover land plowed the previous fall) during the first period of warm weather in early May (Fig. 1).

yields of grain. The field experiments, throughout the spring wheat areas of the United States and Canada, all show conclusively that the highest yields of spring wheat are secured from the earliest spring sowings. In general, these numerous field experiments have shown that spring wheat cannot be sown too early in the spring, provided the soil is dry enough to prepare a good seed bed. The explanation of this, as well as its importance, are shown in the experiments under controlled weather conditions.

The winter wheat field experiments again show the importance of a cool soil during the seedling stage, but associated in this instance with the length of the fall growth period. Experiments, at Wisconsin and elsewhere, have shown that a cool soil in the fall is necessary for highest yields, combined with a growth period of sufficient length for the plant to form a well developed crown and build up a reserve food supply before the extreme winter weather forces the plant into dorm-



FIG. 14.—COLD SOILS AND POOR SEED MEAN REPLANTING CORN

This field of Golden Glow corn on the University Farm at Madison was sown May 4 in a cool soil. The seed was selected in the field from vigorous green plants with well matured ears having dry husks. The rows on the right including row marked "2" were from ears which had been fire-dried and stored in a warm dry place during the winter. The row marked "1" was from an ear of the same seed lot which was stored in the barn without fire-drying. (The two ears with corresponding numbers are shown in the insert). Note the poor stand of weak plants due to seedling blight in row 1 in contrast to the nearly perfect stand of strong plants in row 2. This poor seed would have done much better if planted later in a warm soil.

Select seed corn in the field, fire-dry immediately and store in a warm dry place. Plant on clover or alfalfa land during the first continued warm weather in May.

ancy. Thus, in this instance, the best date of seeding is not dependent upon germination temperatures alone but the duration of growing temperatures as well. The best date of seeding in Wisconsin is the latter half of September, or a period when the soil is cool and yet there is sufficient growing season for the plant to develop a food reserve before winter sets in. (See Table IV.)

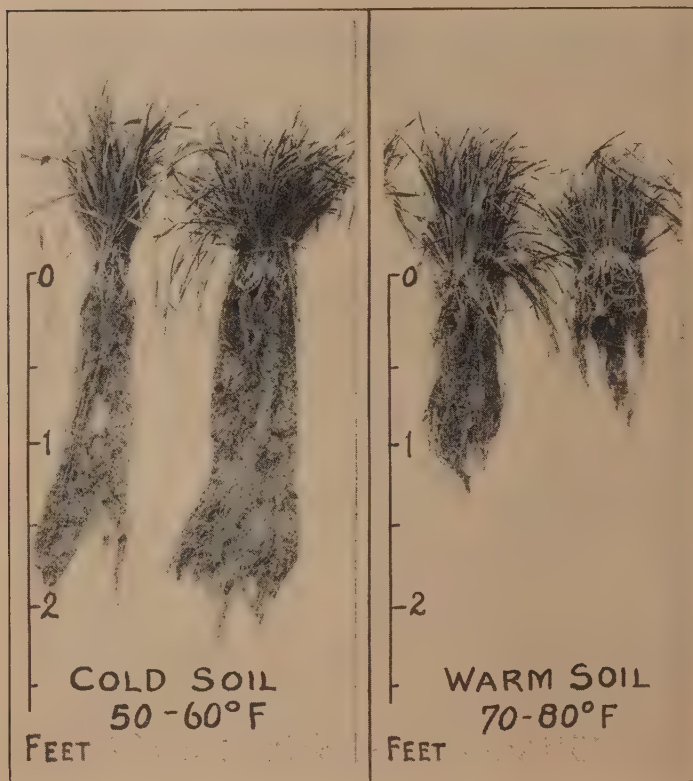


FIG. 15.—COOL SOILS PRODUCE WELL DEVELOPED WHEAT PLANTS WITH LARGE ROOT SYSTEMS

The plants with well developed root systems (left) are better able to withstand hot dry weather during the period of producing grain.

Cool Soil Favors Wheat Plant Development

Low soil temperatures are necessary for strong germination, large root system and generally vigorous, resistant plants. The detailed ex-

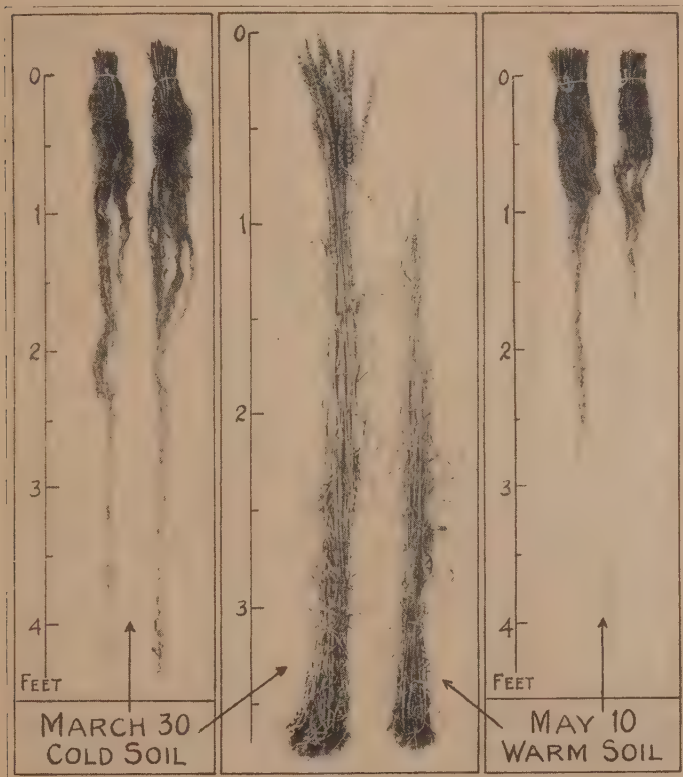


FIG. 16.—SOW SPRING WHEAT EARLY IN A COLD SOIL TO INSURE GOOD ROOT DEVELOPMENT AND HIGH YIELDS

The plants on the left, seeded March 30 in a cold soil, developed a large root system reaching $4\frac{1}{2}$ feet into the soil and produced a high yield of plump grain. In contrast, the plants on the right, seeded May 10 in a warm soil, developed a small root system and produced a low yield of shriveled grain. Sow spring wheat in a cold soil the earliest possible date in the spring.

periments with both spring and winter wheat, grown under controlled weather conditions, help interpret field experiments with the wheat crop. Numerous series of both spring and winter wheat have been grown during the seedling stage, and in many instances to maturity, under controlled temperature and moisture conditions. The germination, root development, crown growth, tillering, head and kernel formation have been studied in relation to the metabolism of the plant.

TABLE IV.—SOW WINTER WHEAT IN A COOL SOIL, JUST EARLY ENOUGH TO STORE RESERVES BEFORE WINTER

	Time of seeding				
	2nd half August	1st half Sept.	2nd half Sept.	1st half October	2nd half October
Average yield of Turkey wheat at Madison, Wisconsin (Bushels)	23	25	26	23	17

*Average of five years experiments conducted by B. D. Leith of the Agronomy Department, Wisconsin College of Agriculture.

And finally, all of these processes of growth have been considered in relation to the development of wheat scab and seedling blight caused by the wheat scab parasite, *Gibberella saubinetii*.

Germination is best in a cold soil. While wheat germinates more rapidly in a warm soil, stockier, stronger seedlings result in a soil below 46°F. Good germination of winter wheat occurs at temperatures just above freezing, resulting in strong seedlings which grow rapidly as the soil temperature is raised following germination. Seedlings, germinated at these low soil temperatures, develop a root system two to three times as large as those grown at higher soil temperatures. (See Fig. 15.)

This is true even when the seedlings are moved to high soil temperatures after germinating in the cold soil. This large root system enables the plant to grow and produce a good crop even under conditions of drought and hot winds later in the season. The same results occur under field conditions as shown in Figure 16, a comparison of the tops and root systems of Marquis wheat plants sown April 22 and May 10.

The plants grown in the cold soil also form the permanent root system deeper in the soil than those in the warm soil. This enables the plant to withstand unfavorable moisture, temperature, and other soil conditions occurring later to disturb growth and yield.

These experiments have shown that the growing conditions during the seedling stage are exceedingly important in determining the subsequent development and yield of the wheat plant. Well rooted, vigorous plants, capable of growing even under unfavorable weather conditions, and resisting disease, especially seedling blight, and maturing before the epidemic of rust and scab occur, result from seeding wheat in a cold soil. The earliest possible date in the spring and the latest safe date in the fall are recommended.

Wheat Scab Develops During Warm, Moist Weather

Wheat scab develops to blight the wheat heads, shrivel the kernels and reduce yields during periods of moist, warm weather when the wheat plant is in blossom. The wheat scab parasite develops in the soil on decaying corn stalks, wheat straw, and other crop refuse throughout the growing season. The parasite forms spores whenever sufficient moisture is present to moisten the crop refuse on the soil

surface. These spores are carried to the wheat heads by wind and air currents. They are capable of producing blight only when there is sufficient moisture to wet the wheat head for a continued period during and immediately following the blossom period. The development of scab is further limited by requiring warm weather along with the continued moisture for scab development. It is evident, therefore, that in this case weather restricts the damage done by this disease, for only occasionally does a period of warm, moist weather occur at the blossom period. When such a condition does occur, the losses are tremendous as, for example, in 1919 when conservative estimates placed the loss due to wheat scab at 80 million bushels. Local epidemics occur in small areas each year as in 1924 when through central and southern Wisconsin heavy losses occurred in spring wheat.

Varieties and strains of wheat have been obtained which show considerable resistance to scab even when grown under "made to order" weather conditions, which favor scab development. Further selection and breeding is necessary, however, before scab resistant strains adapted to the region where scab is prevalent, are available.

The disease can be controlled, however, without resistant varieties. Removing all straw and stalks from the field and plowing under stubble reduces wheat scab.

Sowing clean wheat on soil free from corn stalks, straw, and other crop refuse on the surface will insure against wheat scab. Sowing well adapted, early maturing varieties in a cool soil helps reduce wheat scab losses and losses from seedling blight, caused by the same parasite.

Seedling Blight of Wheat Prevalent in Warm Soils

The wheat scab parasite in the seed, or in the soil, blights the wheat seedling growing in a warm soil. Early field observations showed that wheat infected with the scab parasite, when used as seed and seeded in a warm soil early in the fall, blighted at about the time of emerging from the soil. The same grain, sown late in the fall after the soil was cool, showed little or no blighting. These field observations were checked with greenhouse experiments under controlled weather conditions. In brief, the results show that blighting occurs when the soil temperature is above 46°F. and that, below this temperature, little disease developed from either scabbed kernels or disease infested soil. (See Table V and Figs. 17 and 18)

Seedling blight develops in late seedings of Marquis wheat. Scabbed kernels and clean grain, inoculated with the wheat scab parasite, were sown at successive dates beginning in late March until the middle of May. The seedings made in a cold soil did not develop seedling blight even with scabbed seed. On the other hand, the stand was reduced 50 per cent or more in seedings made in late April and May after the soil temperature had risen above a mean soil temperature of 53°F. (See Table VI and Fig. 19.)

The March and April seedings, during a period of three seasons, have been free from seedling blight and have given well tillered, high yielding



FIG. 17.—SOW WHEAT IN A COLD SOIL TO PREVENT SEEDLING BLIGHT

Note the complete absence of seedling blight at 46°F. and below. Blight increased rapidly with the rise in soil temperature until at 60°F. and above over half of the seedlings were killed by seedling blight caused by the wheat scab parasite.

plants. The highest yield occurred in the field plots sown the earliest possible date in April. (See Fig. 20.)

Seedling blight developed in the early fall seedings of winter wheat. Turkey wheat has been sown at two week intervals from late August until the last of October for a period of six years. Seedling blight developed in the August and September seedings. While in general there was less seedling blight in the October seedings, it has not been advisable to seed much later than October 5 due to winter killing from poorly

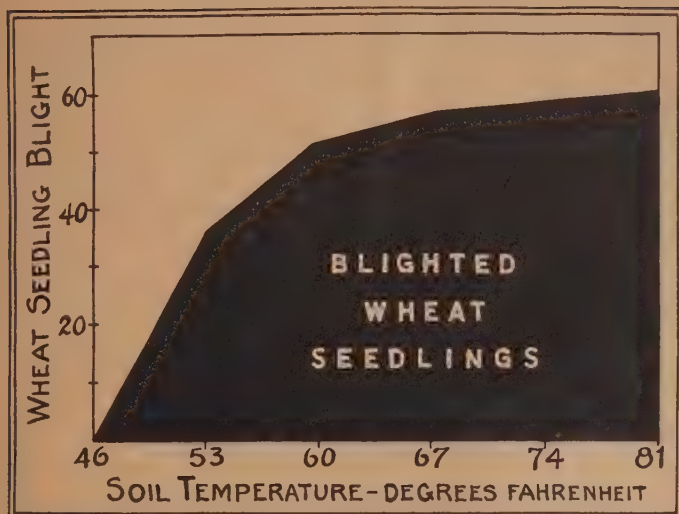


FIG. 18.—WHEAT SEEDLINGS BLIGHT IN A WARM SOIL

The plants grown in a cold soil, below 46°F., were free from disease. In contrast, the plants grown in a warm soil, 60°F., blighted and rotted before emerging. Sow wheat in a cold soil to prevent seedling blight.

developed plants. It is necessary, therefore, to determine the date of seeding in winter wheat by a compromise between cool soil and a sufficient length of fall growing season to enable the plants to form reserves and harden off for the winter period. Late September or early October seedings with scabbed seed, or with clean seed in disease infested soil, have given the best fall and spring stand of plants and highest yields.

TABLE V.—SOIL TEMPERATURE INFLUENCES THE DEVELOPMENT OF SEEDLING BLIGHT OF WHEAT

Soil temp.	Germination		Decrease in germination caused by disease	Healthy plants		Decrease in healthy plants caused by disease
	Clean seed			Clean seed		
	Clean soil	Disease in fested soil		Clean soil	Disease in- fested soil	
Degrees F.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
46	89	90	1	89	90	0
53	85	75	10	85	64	21
60	87	65	22	86	48	33
68	89	68	21	86	43	43
75	79	68	11	77	49	28
82	77	71	16	73	49	34

Seedling blight of wheat can be controlled by seeding clean, scab-free seed in a cold soil. Certain seasons it is impossible to secure scab-free seed. It is advisable under these conditions to treat the seed for thirty minutes in a .5 per cent solution of Uspulun, Semesan, or Germisan, three trade names for organic mercury phenol and cresol compounds. Treated seed sown in a cool soil will give a perfect stand even when sown in disease infested soil. Sow treated wheat the earliest possible date in the spring and the latest safe date in the fall to avoid losses from seedling blight and to secure maximum yields.

TABLE VI.—EARLY SEEDINGS IN COOL SOILS PREVENT SEEDLING BLIGHT OF SPRING WHEAT

Date of seeding	Mean soil temperature	Average percentage stand of healthy plants		
		Clean seed	Clean seed inoculated	Scabbed seed
	Degrees F.	Per cent	Per cent	Per cent
March 31	40	69	74	67
April 22	48	82	79	73
May 1	53	80	38	47
May 10	57	75	28	22

The seedling blight of wheat and corn develop at entirely different soil temperatures. It is interesting to compare the relation of soil temperature to the development of seedling blight, caused by the same parasite in these warm and cool climate crops. With corn, blighting occurred when the seedlings were grown at low soil temperatures, whereas with wheat blighting occurred when the plants were grown at high soil temperatures. In other words, blighting occurred when the plants were under unfavorable weather conditions and sufficiently unbalanced in their growth processes to be unable to withstand attack. Detailed experiments with both host plants, under unfavorable and favorable growth conditions, have shown that when the plant was growing under unfavorable temperature conditions it failed to form well thickened walls around the protective sheaths, and thus allowed the parasite to enter the seedling with little difficulty. Furthermore, the seedling metabolism was so unbalanced that the regular processes of changing the available soluble carbohydrates and nitrogen compounds into stable, less soluble substances and using these for tissue building were checked in certain instances or only partially completed. These results show in general then that weather influences disease development by disturbing and unbalancing the normal processes of metabolism especially in relation to growth and tissue formation.

Weather Important in the Development of Barley Stripe

Weather influences not only the floral infection with the barley stripe fungus but also the subsequent development of this infection in the

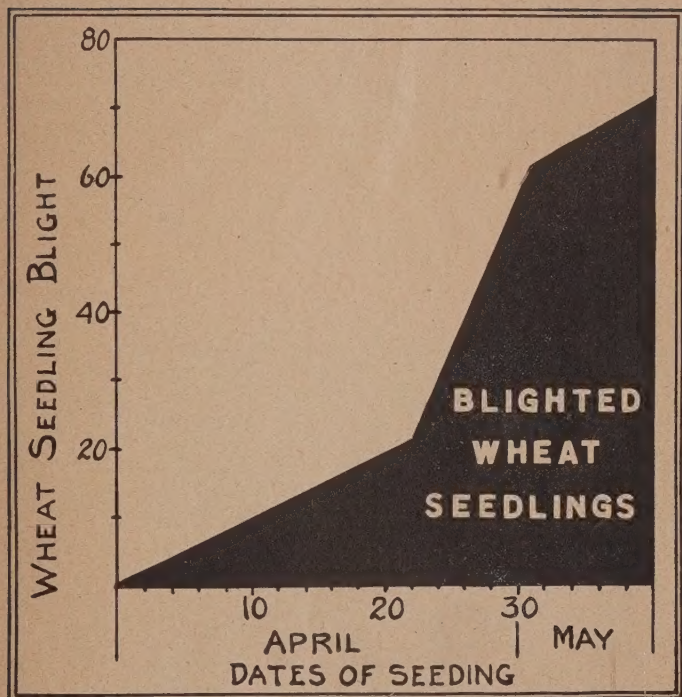


FIG. 19.—SOW SPRING WHEAT THE EARLIEST POSSIBLE DATE IN THE SPRING TO PREVENT SEEDLING BLIGHT

Little or no blight developed in seedlings made in March and early April. Seedlings made later than April 20, when the soil temperature was above 40°F., blighted badly resulting in poor stand and low yields.

growing seedling. Barley stripe is caused by a fungus parasite which invades the healthy immature barley kernel in the field. The fungus remains alive within the coats of the kernel and grows into the young seedling during germination in the spring. The parasite grows with the barley seedling during the spring and finally the disease manifests itself just before heading by yellow to brown stripes in all the barley leaves. The stripes in the lower leaves turn brown while the stripes in the newer leaves above are still yellow. Finally, all the leaves at heading are brown striped and split or frayed along the stripes. The heads are blighted, brown colored and frequently only partly emerged from the boot. These striped plants do not bear grain and, therefore, are a complete loss. The parasite produces spores, or seeds on these striped plants at blossom time. These spores are carried to the healthy heads by wind currents where they grow during moist weather to penetrate the kernels and repeat the life cycle. Moist, warm weather when the

barley is in blossom, therefore, insures a high percentage of stripe infection if there are even a few striped plants in the field. When once established within the kernel the parasite can live in a dormant condition indefinitely to commence growth again when the grain germinates.

Here again, soil temperature and soil moisture are factors in determining the number of these seedlings which will succumb to the stripe disease. Detailed studies under controlled weather conditions to determine the exact nature of seedling invasion and the influence of weather upon disease development have not been conducted with this disease. Field experiments, however, have shown wide seasonal variations in the amount of stripe developing from year to year using the same seed each year.



FIG. 20.—EARLY AND LATE SEEDLINGS OF MARQUIS WHEAT

Clean seed and scabbed seed alike produced a good stand and high yield when sown in a cold soil. Clean seed produced a good stand but yielded poorly in a warm soil, whereas scabbed seed was a total loss, due to seedling blight, when sown late in a warm soil.

Seasonal Spring Growing Conditions Influence Barley Stripe

Weather and soil conditions during the seedling stage influence the development of the barley stripe disease. Soil temperature, soil moisture, and soil fertility all affect the severity of the disease and thus largely determine the number of seedlings which may outgrow the disease on the one hand, or which may be killed in the seedling stage on the other. These studies upon the relation of weather and soil conditions to the development of the stripe disease have been limited to field experiments which have consisted chiefly of seeding badly infected seed year after year and at different dates in the same year.

The amount of stripe developing varies from year to year. Wisconsin Pedigree No. 6 barley grown in 1922 has been sown in early April on the same soil each season since 1923. The number of striped plants developing each year have been determined in an average of 30 rod rows. The striped plants resulting varied from 11 plants per rod row, which developed the stripe disease in 1923, to 26 per rod row in 1925. The striped plants were more than doubled in 1925 when the seed was sown in a cool wet soil in contrast with the seeding in a cool moderately dry soil in 1922. The same results were obtained by seeding at different dates.

Seeding barley at different dates in the spring affects the development of stripe disease. During the 1925 season Wisconsin Pedigree No. 6 barley seed lots grown in 1922 and also in 1924 were sown April 11, in a cool, wet soil and May 9, in a cool, dry soil. The amount of stripe developing under the different conditions is shown in Table VII.

TABLE VII.—SOW BARLEY IN A COOL MOIST SOIL TO REDUCE LOSSES FROM STRIPE DISEASE

Date of seeding	Soil temperature °F.	Soil moisture per cent	Ave. number striped plants per rod row		
			1922 seed	1924 seed	Average of two seed lots
April 11, 1925.....	51 (cool)	26 (wet)	26	23	24.5
May 9, 1925.....	52 (cool)	15 (moist)	8	5	6.5

The experiments upon barley stripe have shown that seeding very early in a wet, cold soil increases the losses from barley stripe. The barley plants develop best and give the highest yield when seeded in a moderately cool soil, about 55°F. The later seedings in a warm, dryer soil are in general more free from the stripe disease but yields are greatly reduced due to the late seeding. A safe compromise can be used in seeding barley later than wheat and oats when the soil is still cool and moist by treating the seed for the control of stripe.

The stripe disease of barley can be controlled by seed treatment. This treatment, to successfully control barley stripe, must eliminate all

⁴Leukel, R. W., J. G. Dickson, and A. G. Johnson. Seed Treatment Experiments for Controlling Stripe Disease of Barley. In *Phytopathology*.

of the diseased plants and thus prevent further infection of the barley seed the following year. Extensive experiments⁴ conducted during the past four years have demonstrated that the new mercury-cresol and mercury-phenol compounds are very effective in controlling barley stripe without injuring the germination of the seed. Germisan, a mercury-cresol compound, has given complete control of stripe when the grain was soaked one hour in a one-half to one-fourth per cent solution of this substance in water. (4 oz. Germisan in 10 gallons water. Soak the seed in this solution for 1 hr.). The trade compounds, Uspulun and Semesan, mercury-phenol substances, while not as satisfactory as Germisan have given good results in controlling barley stripe when used in slightly stronger concentrations for the same length of time (6 oz. Uspulun or Semesan in 10 gallons water. Soak the seed in this solution for 1 hour).

Barley stripe can be controlled, and yields increased, by treating the seed and seeding in a moderately cool, moist soil. The barley smuts are likewise controlled by this treatment and seeding in a moderately cool soil. It is possible, therefore, to sow barley earlier in the spring, by treating the seed with Germisan, Uspulun, or Semesan and thus mature the crop before the yields are lowered by the hot summer weather and by attack from stem rust.